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RESEARCH ARTICLE

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Effect of Varying Temperature by Covered Plastic Film on Growth and Development of Chickpea

Anurag Satpathi, A.S. Nain, Parul Setiya

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ABSTRACT

Background: Climate change has become a major challenge in cultivation of chickpea and productivity. Negative impacts of climate change are likely to result from the effects of high temperature, low temperature, drought and excessive moisture and these factors affect crop yield ultimately.

Methods: Keeping in view for quantifying the effects an experiment was laid out in split plot design. The experiment with three dates of sowing *i.e.* 12th December 2018 (D_1), 22nd December 2019 (D_2) and 2nd January 2019 (D_3) as main plot treatments and the four microclimatic regimes *viz.* open field (T_1), Open roof (T_2), perforated roof (T_3) and closed or packed (T_4) by 100 GSM plastic film as sub plot treatments was laid to analyse the impact of temperature variation.

Result: The major finding of the study is that the chickpea crop sown on 12th Dec. (D1) found highest grain yield (1200 kg ha^{-1}) as compared to 22nd Dec. (845 kg ha^{-1}) and 2nd Jan. (638 kg ha^{-1}). This may be mainly attributed to congenial weather during the entire growing period. By studying the role of weather variables on chickpea in terms of seed yield, it is noticed that best performance of Packed subset (T_4) *i.e.* 1044 kg ha^{-1} was observed in all dates of sowing followed by Perforated (T_3) *i.e.* 955 kg ha^{-1}, Open roof (T_2) *i.e.* 813 kg ha^{-1} and Open field (T_1) *i.e.*765 kg ha^{-1}.

Key words: Chickpea, Pusa-362, Plastic film, Split plot design, Temperature.

INTRODUCTION

The chickpea (*Cicer arietinum* L.) is an important food legume, ranking third among all pulses crop (FAO, 2014). Chickpea is grown in 50 countries around the world under a wide range of environments. At present, chickpea crop is grown on an area of about 12.14 million hectares with an average yield of 9.51 million tons and production of 877 kilograms/ha. India contributes to 67% of the chickpea production (Jumrani and Bhatia, 2014). It is an excellent source of quality protein for vegetarian population of India (Singh and Singh, 2018).

Climate change has become a major challenge in chickpea cultivation and productivity. Climate change is likely to negatively impact the crop yield because of high temperature, low temperature, drought and excessive moisture. Number of researchers (Summerfield *et al*., 1990; Singh *et al*., 1994; Basu *et al*., 2009) reported that among all the abiotic constraints, high temperature is one of the most important constraints that have a detrimental effect on chickpea growth and yield over a range of environments. Changes in climate events and extreme weather have been observed in recent past years. The heat wave frequency has increased in different parts of Asia, Europe and Australia. The global mean surface temperature of the earth for the mid and late 21st century is estimated to rise by 2°C which will lead to a severe variation in precipitation events, more heat waves and fewer cold temperature extremes. These types of changes in climate will affect chickpea production which will reduce the grain yield by 19% (Kadiyala, 2016). Neenu *et al*., (2013) also reported that the effect of increased temperature on crop yield is negative in tropical and subtropical regions but positive in temperate regions.

Department of Agrometeorology, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, India.

Corresponding Author: Anurag Satpathi, Department of Agrometeorology, College of Agriculture, G.B. Pant University of Agriculture and Technology, Pantnagar-263 145, Uttarakhand, India. Email: anuragsatpathi50@gmail.com

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There are several studies reporting reduced yield as a result of high temperatures (Kalra *et al*., 2008). Addition to this, number of studies reported the adverse effect of high temperatures on seed germination, photosynthesis, transpiration efficiency, membrane stability, nutrients partitioning, fertilization and pollen production. Hence the effect of temperature is a very important aspect of study in chickpea production.

Additionally, number of environmental and genetic variables affect the growing period of chickpea in determining its productivity. Optimum sowing time of chickpea varies among cultivars and also from one region to another due to variation of agro-ecological conditions (Tokraman *et al.* 2018). Chickpea (*Cicer arietinum* L.) is a cool season pulse crop and has been reported sensitive to high temperature (Wang *et al.* 2006). During germination and seedling establishment, chickpea crop experiences low temperature while, during flowering and seed formation it exposed to high temperature and it may cause a severe reduction in yield. It incurs yield losses when exposed to high temperatures at reproductive stage (Rai *et al.* 2016). Heat stress at reproductive stage is increasingly becoming a serious constraint to chickpea production (Wang *et al.* 2006, Bahuguna *et al.* 2012).

Therefore, the objective of this study was to understand the physiological response of chickpea yield and its attributes when crop is grown under different temperature regimes. Keeping in view all these facts an experiment was conducted during rabi 2018-19 to studying the impact of modified microclimate (temperature) on growth and development of chickpea (*Cicer arietinum* L.) in tarai region of Uttarakhand.

MATERIALS AND METHODS

The experiment was performed during December to April 2018. Study was conducted in the N.E. Borlaug crop research centre of Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar (Uttarakhand). The study area lies in the Tarai belt of Shivalik range of Himalayas (29°3′0″ N, 79°31′0″E and a height of 243 m from Mean Sea Level). The average annual rainfall in Pantnagar region is approximately 1400 mm, 80% of which is occurred from June to September *via* the South-West monsoon.

Planting of chickpea

The split plot design was used where, date of sowings were used as main plot treatment. The three dates of sowings were 12th December 2018 (D_1), 22nd December 2018 (D_2) and 2nd January 2019 (D_3). The different degree of perforation was used as subplot treatment. The row to row distance was 30cm. Plant to plant distance was not maintained at the time of sowing but acquired later by thinning. The depth of the sowing was maintained 5-6 cm, whereas plot to plot distance was kept around 1 m.

Temperature treatments

To induce variation in temperature and humidity under different experimental combinations, polythene sheets of 100 GSM thicknesses were used. These sheets were used with different degrees of perforation in one-meter square area. Bamboo sticks were used to hold the structure made by these polythene sheets. In total there were four type of situations under which crop was grown.

As illustrated in Fig 2, the first one (T_1) was Open Field, where no covering takes place in these types of sub-plots, which means in these plots the crop grow under normal weather conditions without any modification. These were standard plots that have been used to make a comparison with other plots in terms of growth, development and yield with other treatments. The second one (T_2) was open roof condition, where sub-plots of one-meter square area was covered only from the sides but the top was remain open. In these sub-plots, there is a less significant change in temperature as compared to the outside field or fully open field. However, the effect of wind is less in these sub-plots, which results in low water loss. The third one (T_3) was perforated roof type, where one-meter square sub-plots were covered fully with all four sides and the roof sheets were perforated equally with the help of a sharp metal. The inside temperature in this type of structure is high as compared to the outside field but low as compared to fully closed structures. The perforation allows limited air exchange as well as retards outgoing long wave radiation depending upon perforation. The fourth and last type (T_4) is closed or packed type subsets, where subplots of one meter square area were completely covered in all sides with semi-transparent polythene material. The purpose of the application of these sheets is to increase the temperature inside the structures. The polythene cover retards air movement and therefore check the mixing of canopy air with the air adjacent. The packed structure also leads to an increase in the inside humidity which results into reduced evapotranspiration demand.

Data collection and analysis

The chemical and physical properties of the soil in experimental site are presented in Table 1. Data of precipitation, maximum and minimum daily temperatures, collected by the Department of Agrometeorology, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India, during the experiment are presented in Table 2 and Fig 1. The daily minimum and maximum

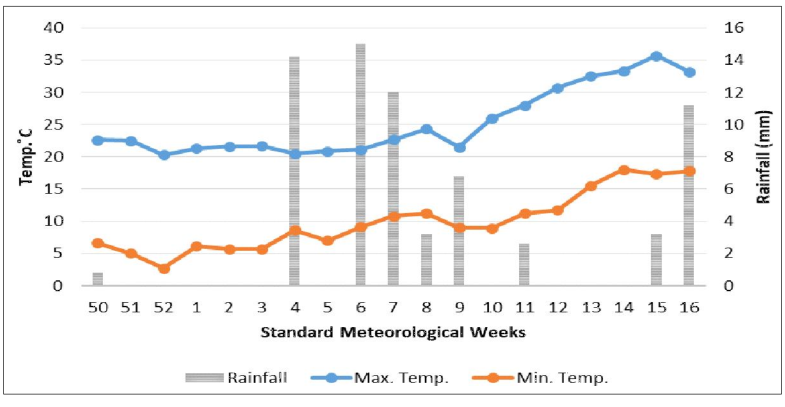


Fig 1: Weekly meteorological observations in experimental site.

temperature inside the structures is measured by Thermo-hygrometer. Average minimum and maximum temperature for each growth stages are presented in Table 3 and Fig 5.

The growth variables analysed were the heights of plants, plant biomass and LAI (Leaf area index) at branching, flowering and physiological maturity stages of growth and development. Yield and yield attributing characters were recorded and analysed at the time of harvesting.

Statistical analysis

Statistical analysis was carried out to find out the significant differences of the above-mentioned growth parameters of yield and yield attributes between various treatment combinations. ANOVA (Analysis of Variance) technique applicable in split-plot design was used for the analysis of recorded observations. Additionally, Pearson correlation analysis was performed to examine the association of

Table 1: Chemical and physical properties of soil of the experimental site.

		Soil physical properties			
Depth	Sand (%)	Silt (%)	Clay (%)	Texture	BD
0-15 cm	27.7	55.0	17.3	Silty loam	1.45
15-30 cm	27.4	54.7	17.9	Silty loam	1.48
		Soil chemical properties			
Depth	N (kg/ha)	P (kg/ha)	K (kg/ha)	OC (%)	
0-15 cm	207.3	23.6	248.1	1.4	
15-30 cm	183.6	19.8	223.8	0.78	

Table 2: Maximum, minimum and mean temperature, precipitation and relative humidity during the period of experiment was conducted.

Climatic characteristics	Month				
	Dec	Jan	Feb	Mar	Apr
T°C Maximum	21.8	21.3	22.3	27.7	34.0
T°C Minimum	4.5	6.5	9.5	11.2	17.7
T°C Mean	13.1	13.9	15.9	19.4	25.9
Precipitation (mm)	0.8	14.2	33.4	6.2	14.4
Mean relative humidity (%)	75.7	73.7	78.8	68.7	52.7

Fig 2: Different treatment subsets to induce temperature variation.

phenophases with maximum and minimum temperature. Along with this, the correlation of yield attributes with maximum and minimum temperature was also evaluated. Significance level of 5% has been used to examine the results.

RESULTS AND DISCUSSION

The present study was carried out to investigate the effect of varying temperature by covered plastic film on growth and development of chickpea. The chickpea cultivar was grown under four environmental conditions. Due to different dates of sowing and polythene sheets of different degrees of perforation the temperature regimes were changed at various phenophases of the crop (Table 3 and Fig 5). The maximum/minimum temperatures observed in these environmental conditions are 25/10°C (open field), 26/11°C (open roof), 28/13°C (perforated roof) and 30/15°C (closed or packed) with average temperatures of 17.5, 18.5, 20.5 and 22.5°C respectively. Different plastic covering conditions with different temperature regimes showed significant effect on growth and yield parameters at various growth stages (Table 4 and Table 5).

Effect of temperature on phenology

The increasing temperatures reduced the duration required to complete different phenophases and also reduced the total crop growth duration (Fig 3). The average days of flowering for open field was 62 days which was significantly reduced to 61, 56 and 53 days when plants were grown under 25/10°C, 26/11°C, 28/13°C and 30/15°C maximum and minimum temperatures, respectively. Table 6

Table 3: Maximum and minimum temperature observations at different growth stages.

Treatment	Germination		Branching		Flowering		Pod formation		Physiological maturity		Harvesting maturity	
	TM	Tm	TM	Tm	TM	Tm	TM	Tm	TM	Tm	TM	Tm
D_1T_1	22.6	5.8	21.4	4.6	21.4	7.8	23.5	11.0	28.0	12.2	34.4	17.8
D_1T_2	23.0	6.1	22.1	4.1	22.3	8.9	24.6	12.4	29.2	13.5	35.6	18.9
D_1T_3	25.5	9.2	24.6	7.2	24.5	10.2	26.4	13.7	30.3	14.5	37.5	20.8
D_1T_4	27.6	10.9	27.1	9.5	26.7	12.3	28.4	15.9	31.7	16.3	38.8	22.3
D_2T_1	21.4	3.9	21.1	4.8	21.9	8.7	22.9	10.1	28.7	12.4	34.7	17.7
D_2T_2	22.0	4.1	21.8	5.7	22.3	9.3	24.1	11.7	28.3	12.5	36.0	18.8
D_2T_3	24.6	7.2	24.6	8.0	24.3	10.7	26.4	13.7	31.2	15.5	37.9	20.8
D_2T_4	27.1	9.5	27.2	10.5	26.3	12.8	28.4	15.9	32.4	16.6	38.7	22.1
D_3T_1	21.5	5.9	21.7	5.7	21.8	9.3	21.9	10.0	30.1	13.1	34.7	17.7
D_3T_2	22.2	7.1	22.4	6.8	22.9	10.5	22.9	11.1	31.2	14.2	35.3	18.8
D_3T_3	25.0	9.0	24.7	8.7	25.0	12.3	26.4	13.7	33.4	16.4	37.5	20.8
D_3T_4	27.6	11.4	27.7	11.4	26.9	14.2	27.7	15.2	33.8	17.7	38.7	22.1

* TM = Maximum temperature, Tm = Minimum temperature.

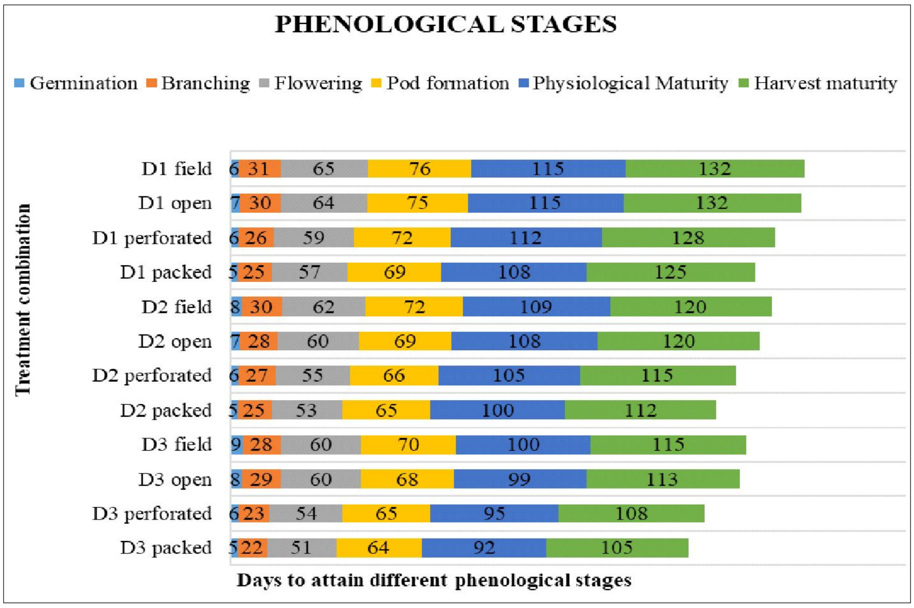


Fig 3: Time taken by the plants (in days) to attain different phenological stages.

demonstrated a significant strong negative correlation of onset of flowering with maximum/minimum temperatures (r_p = -0.993, p<0.007 and r_p = -0.977, p<0.023). Due to high temperature in late sowing, the crop was able to absorb more heat units in comparatively shorter time which resulted in early initiation of flowering. Days taken for physiological maturity were reduced with delay in sowing and increase in temperature. The chickpea plants matured at 122, 122, 117 and 114 days, respectively when grown at 25/10°C, 26/11°C, 28/13°C and 30/15°C maximum and minimum temperatures, respectively. A strong negative and significant correlation was found between harvesting maturity and maximum/ minimum temperatures (r_p = -0.997, p<0.003 and r_p = -0.985, p<0.015) as shown in Table 6.

Effect of temperature on vegetative growth

Plant population per meter square, plant height, LAI and biomass were observed maximum for first date of sowing (12th December) and under closed condition having 30/15°C maximum/minimum temperatures as compared to plants

Table 4: Influence of dates of sowing and degree of perforation on growth and yield components of chickpea.

Tr. no.	Treatment	Plant population m^{-2}	Plant Height (cm)	LAI	Plant Biomass (g)	No. of pods per plant	No. of seeds per pod	100 seed weight
				Days of sowing				
1	12th December	29	46.33	2.59	13.49	27.31	1.19	26.70
2	22nd December	27	43.17	2.40	11.20	25.93	1.14	24.82
3	2nd January	27	40.83	2.18	10.29	19.95	1.12	22.11
	SE m±	0.647	0.991	0.028	0.147	0.561	0.015	0.338
	CD (5%)	NS	3.994	0.112	0.591	2.262	NS	1.361
				Degree of perforation (Maximum/Minimum temperature)				
1	T_1 (25/10°C)	24	39.22	2.03	10.39	25.67	1.17	23.32
2	T_2 (26/11°C)	25	39.67	2.16	10.84	25.02	1.15	24.16
3	T_3 (28/13°C)	30	46.11	2.58	12.56	24.44	1.14	25.25
4	T_4 (30/15°C)	33	48.78	2.85	12.85	22.44	1.13	25.45
	SE m±	0.716	0.728	0.058	0.183	0.759	0.013	0.495
	CD (5%)	2.143	2.179	0.174	0.549	2.271	NS	1.482

Table 5: Influence of dates of sowing and degree of perforation on yield of chickpea.

Tr. no.	Treatment	Straw yield (kg/ha)	Seed yield (kg/ha)	Harvest index (%)
1	12th December	2780	1200	43
2	22nd December	2405	846	35
3	2nd January	1961	638	32
	SE m±	32.31	31.82	1.3
	CD (5%)	130.26	128.3	5.4
1	T_1 (25/10°C)	2149	765	35
2	T_2 (26/11°C)	2268	813	35
3	T_3 (28/13°C)	2506	955	37
4	T_4 (30/15°C)	2607	1044	39
	SE m±	31.07	36.49	1.6
	CD (5%)	93.03	109.28	NS

Table 6: Correlation of phenophases with minimum, maximum temperature.

	Tmax	Tmin	Germination	Branching	Flowering	Pod formation	Physiological Imaturity	Harvest maturity
Tmax	-							
Tmin	0.995**	-						
Germination	-0.999***	-0.992**	-					
Branching	-0.989*	-0.970*	0.990**	-				
Flowering	-0.993**	-0.977*	0.994**	0.999***	-			
Pod formation	-0.987*	-0.981*	0.981*	0.983*	0.984*	-		
Physiological maturity	-0.990**	-0.991**	0.992**	0.965*	0.973*	0.956*	-	
Harvest maturity	-0.997**	-0.985*	0.999**	0.993**	0.996**	0.976*	0.989*	-

Table 7: Correlation of yield attributes with minimum, maximum temperature.

	Seed yield	Straw yield	Pods/ plant	100 seed weight	Seeds/pod	Harvest index	Tmax	Tmin
Seed yield	-							
Straw yield	0.993**	-						
Pods/plant	-0.941	-0.909	-					
100 seed weight	0.962*	0.987*	-0.850	-				
Seeds/pod	-0.970*	-0.977*	0.943	-0.968*	-			
Harvest index	0.991**	0.970*	-0.946	0.919	-0.937	-		
Tmax	0.999**	0.987*	-0.957*	0.950	-0.971*	0.993**	-	
Tmin	0.990**	0.976*	-0.978*	0.938	-0.980*	0.983*	0.995**	-

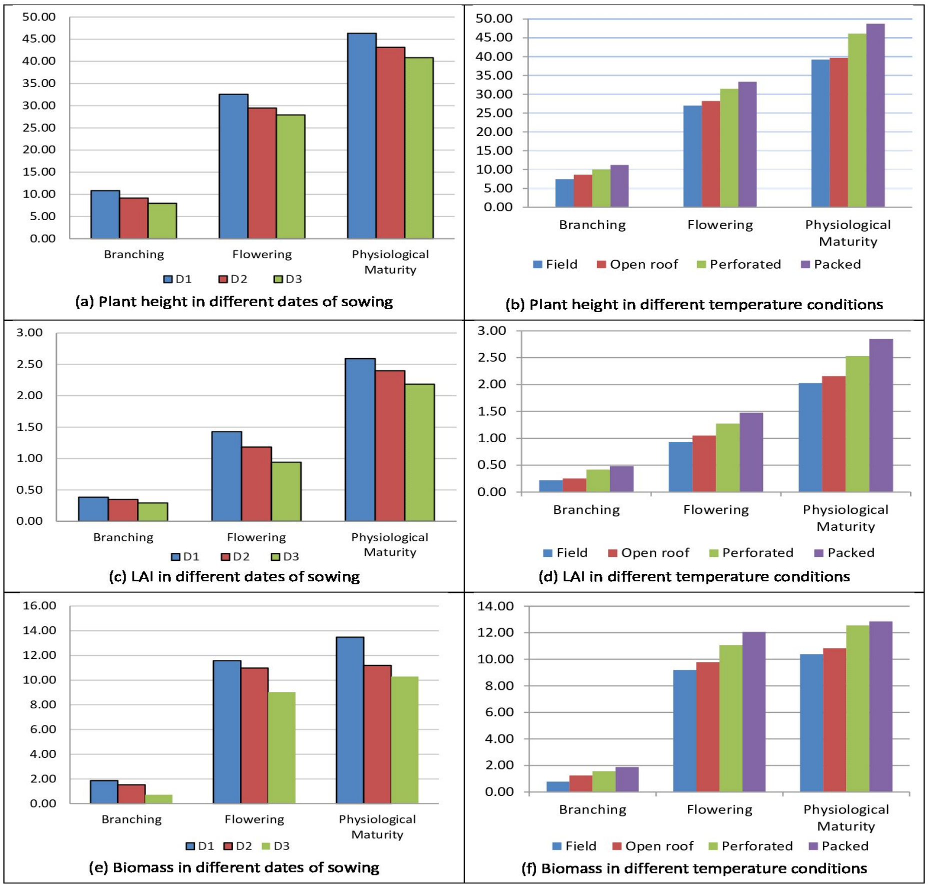
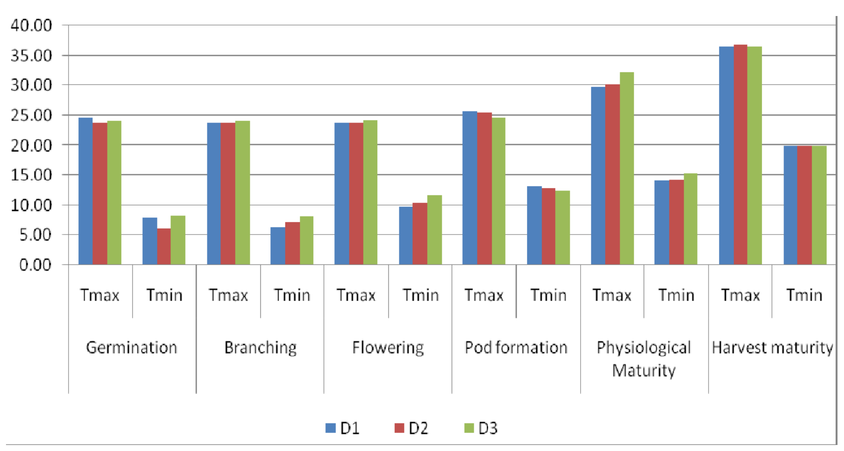


Fig 4: Plant height, LAI and biomass observations during branching, flowering and physiological maturity stages.

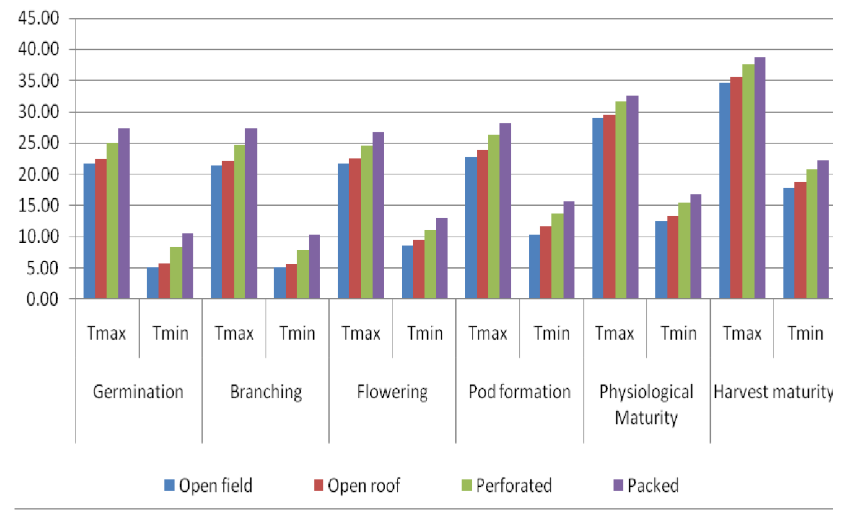
grown below this temperature (Table 4, Fig 4). The finding shows that sowing at the end of first fortnight of December and under closed environment condition was best for the growth and development of chickpea crop. Tyagi (2014) also concluded that the average temperature of 24.4°C was optimum for higher growth and yield of chickpea as it provides the optimal thermal requirements for various plants processes.

Effect of temperature on yield and its attributes

Dates of sowing and plastic covering conditions with different temperature regimes showed significant effect on crop yield and yield attributes. As shown in Fig 6, the degree to which the yield was increased by increasing temperatures was higher for first date of sowing: 12th December (R^2 = 0.989) followed by second date of sowing: 22nd December) (R^2 = 0.972) and third date of sowing: 2nd January (R^2 = 0.875). 100 seed weight, straw yield, seed yield and harvest index were also observed maximum on first date of sowing (12th December) and under closed environment condition having maximum and minimum temperature 15 and 30°C respectively (Table 4 and Table 5). Suneeta *et al.* (2011) also found that 25°C to 30°C temperature range was optimum for better seed yield of chickpea. Addition to this, minimum 100 seed weight, straw yield, seed yield and harvest index were observed on third date of sowing and under open field environment condition (Table 5). Thus, the



(a)



(b)

Fig 5: (a) Maximum and minimum temperature during different growth and development stages in different dates of sowing. (b) Maximum and minimum temperature during different growth and development stages in different plastic covering conditions.

finding shows that late sowing (in the month of January) and open environment condition having temperature range between 10/25°C was not favourable for the growth and development of chickpea crop. Further, the high yield at first date of sowing may be due to availability of a greater number of days for maturity (Fig 3). Besides this, in case of timely sowing, due to lower temperature during reproductive phase, longer grain filling period was available which resulted in better pod development and consequently, higher yield. Similar significant effect of sowing dates on yield components of chickpea is also reported by Singh *et al.* (2014). The results (Table 7) indicated a strong positive correlation of maximum/minimum temperatures with 100 seed weight (r_p= 0.950, p<0.050 and r_p = 0.938, p<0.062), though this correlation was not significant. Addition to this a strong significant positive correlation of maximum/minimum temperatures with straw yield (r_p= 0.987, p<0.013 and r_p = 0.976, p<0.024), seed yield (r_p= 0.999, p<0.001 and r_p = 0.990, p<0.010) and harvest index (r_p= 0.993, p<0.007 and r_p = 0.983, p<0.017) were found. Moreover, the result shows that after 30/15°C temperature range (closed conditions), 28/13°C temperature range (perforated roof condition) was better as compared to the 26/11°C temperature range (open roof condition) and 25/10°C temperature range (open field) for the growth and development of chickpea (Table 4 and Table 5).

Addition to the above, strong significant and negative correlation was found between number of pods per plant and maximum/minimum temperature (r_p= -0.957, p<0.043 and r_p = 0.978, p<0.022), shown in Table 7. The results (Table 4) demonstrates that the highest number of pods per plant was recorded on first date of sowing (12th December) and under open field condition (10/25°C), whereas the minimum number of pods per plant was recorded on third date of sowing (2nd January) and closed condition (15/30°C). The plants of packed and perforated environment exposed

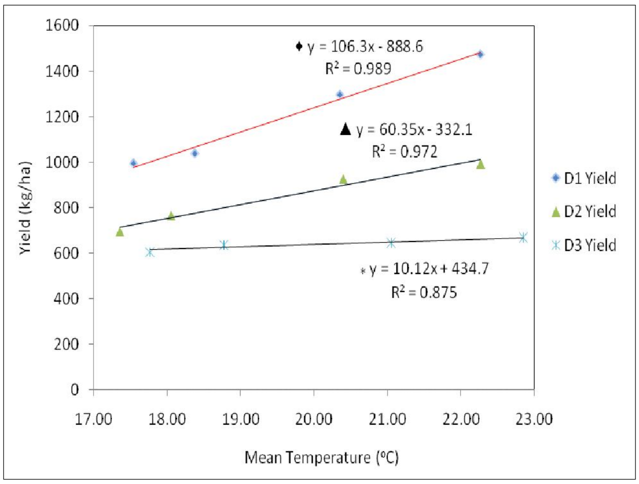


Fig 6: Association of mean temperature with chickpea yield at different dates of sowing.

to higher temperature during flowering and maturity stage which results in pollen loss and less pod formation. This finding was like the findings of Tyagi (2014) and Kiran *et al.* (2015). Though, the number of pods was less in the closed environment condition, but it resulted in high yield compared to the other environment conditions due to the high plant population per unit area and higher seed weight (Table 4).

CONCLUSION

The finding shows that closed roof condition which has a temperature range between 15/30°C was best for the development and growth of chickpea followed by perforated roof condition having temperature range between 13/28°C. Besides this, sowing at the first fortnight of December shows better results as compared to the sowing at the second fortnight of December and first fortnight of January. The experiment clearly indicated that different temperature ranges significantly influenced the phenology, growth in terms of leaf area index, yield and yield attributes in chickpea.

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